maintain these institutions dynamically, the kind of dynamic causation that is present in economics and ecology.

In order to plan for sustainability, we need to know, and we need to integrate, how information is evaluated and counterproductive information rejected. How is new "knowledge" created from competing information sources and incorporated with useful existing knowledge? Which processes create novelty, which smother innovation, which foster it? Those questions are explored in Chapters 4, 5, and 13. Neither ecology, nor economics, nor institutional theory now deals well with these fundamental questions of innovation, emergence, and opportunity. That is what evolutionary theory is about.

Evolution and Complex Systems

The emergence of novelty that creates unpredictable opportunity is at the heart of sustainable development (Holling 1994b). Biological evolutionary theory—which can be expanded to include cultural evolution—deals with just this process. The new field of complexity studies sees ecological, economic, and social systems as being similar to biological processes that generate variability and expose the patterns that result to selective forces. But, like each of the other fields, the representations are partial. They are detached from deep knowledge of the key natural and human processes, and from convincing tests of the adequacy and credibility of the results.

In this book we argue that the process of developing policies and investments for sustainability requires a worldview that integrates ecological with economic with institutional with evolutionary theory—that overcomes disconnects due to limitations of each field. But as compelling and easy as it is to criticize disciplinary gaps, they are clearly not the only reason for unsustainable practices. There are other, deeper limitations that arise from worldviews that people hold. These worldviews are also partial representations of reality: representations that are valuable because they provide temporary certitude to allow action, but whose partial nature ultimately exposes their inadequacy. They are caricatures of aspects of reality.

Caricatures of Nature

Although some of the failures of complex resource systems are due to limitations in disciplinary theories and experience, others can be traced to differences among the worldviews or myths that people hold. In this section we identify at least five such caricatures that underlie explanations of how nature works and the implications of those assumptions on subsequent policies and actions (Figure 1-1). Each of these caricatures, or myths, leads to different assumptions about stability, different perceptions of the processes that affect that stability, and different policies that are deemed appropriate (Table 1-1). We begin with the most static view: that of a nature lacking stabilizing forces—"Nature Flat."

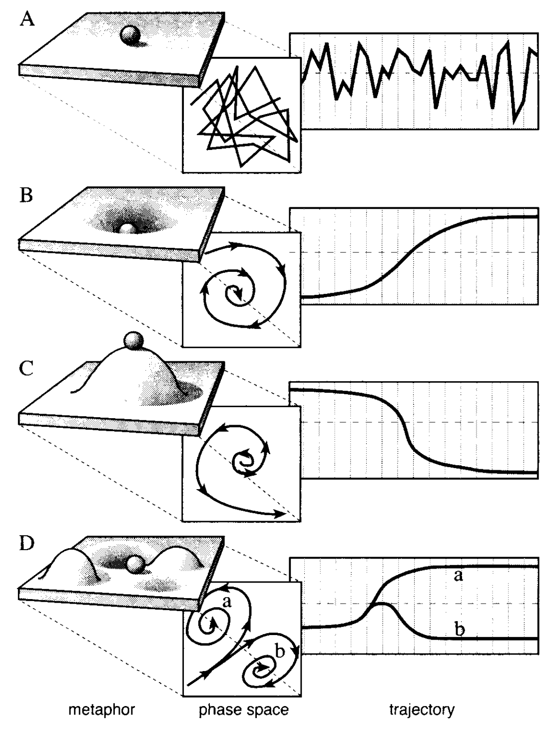


Figure 1-1. Depictions of four myths of nature: (A) Nature Flat, (B) Nature Balanced, (C) Nature Anarchic, and (D) Nature Resilient. Each myth has three representations or metaphors: as stability landscape (left), phase diagram (center), and time-course chart or trajectory of key system variables over time (right).

Nature Flat. In this view, "flat" is used to describe a system in which there are few or no forces affecting stability. There are therefore few limitations on the ability of humans to change nature. There are no feedbacks or consequences from nature of human actions. It is much like rolling a ball around on a cookie sheet (Figure 1-1 A). The processes that affect the position of the ball—i.e., state of nature—are random or stochastic. In such a view of nature, policies and politics are random as well, often described as "garbage can" politics (March and Olsen 1989; Warglien and Masuch 1996). It is a nature that is infinitely malleable and amenable to human control and domination if only the "right" values and the "right" timing are chosen. The issues of resource use, development, and control are identified as issues that are exclusively of human action, issues that can be resolved by community activism or stakeholder control. Alternatively, it can be a view of cornucopian nature where human ingenuity and knowledge surmount all obstacles to produce exponential growth. Such a "flat worlder" view is not wrong, just incomplete. There are indeed strong stochastic elements; the timing of decisions is important. Human ingenuity is a powerful force for change.

Table 1-1. Characteristics of Alternative Views or Myths of Nature

	Stability	Processes	Policies	Consequence
Nature Flat	none	stochastic	random	trial and error
Nature Balanced	globally stable	negative feedback	optimize or return to equilibrium	pathology of surprise
Nature Anarchic	globally unstable	positive feedback	precautionary principle	status quo
Nature Resilient	multiple stable states	exogenous input and internal feedback	maintain variability	recovery at local scales or adaptation; structural surprise
Nature Evolving	shifting stability landscape	multiple scales and discontinuous structures	flexible and actively adaptive, probing	active learning and new institutions

Nature Balanced. The second myth is a view of nature existing at or near an equilibrium condition (Figure 1-1 B). That equilibrium can be a static one or a dynamic one. Hence if nature is disturbed, it will return to an equilibrium through (in systems terms) negative feedback. Nature appears to be infinitely forgiving. It is the myth of maximum sustainable yield and of achieving fixed carrying capacities for animals and humanity. It imposes a static goal on a dynamic system. This view of nature underpins prescriptions for logistic growth, where the issue is how to navigate a looming and turbulent transition—demographic, economic, social, and environmental—to a sustained plateau. This is the view of several organizations with a mandate for reforming global resource and environmental policy—of the Brundtland Commission, the World Resources Institute, the International Institute of Applied Systems Analysis, and the International Institute for Sustainable Development. Many individuals in these and similar institutions are contributing skillful scholarship and policy innovation. They are among some of the most effective forces for change, but the static assumptions can create the very surprise and crisis they wish to avoid. The "balanced worlder" view is

also not wrong—just incomplete. There are indeed, forces of balance in the world, forces that can become overwhelmed.

Nature Anarchic. If the previous myth is one where the system stability could be defined as a ball at the bottom of a cup, this myth is one of a ball at the top of a hill (Figure 1-1 C). It is globally unstable. It is a view dominated by hyperbolic processes of growth and collapse, where increase is inevitably followed by decrease. It is a view of fundamental instability, where persistence is possible only in a decentralized system where there are minimal demands on nature. It is the view of Schumacher (1973) and some environmentalists. If the Nature Flat view assumes that infinitely ingenious humans do not need to learn anything different, this view assumes that humans are incapable of learning. This is implicit in the writings of Tenner (1996), where he argues that all technology that is unleashed will eventually "bite back." This view presumes that small is beautiful, because the inevitable catastrophe of any policy must be kept localized. It is a view where the precautionary principle of policy dominates, and social activity is focused on maintenance of the status quo. The "anarchist worlder" view is also not wrong—just incomplete. There are indeed destabilizing forces, and there is a value in diversity of the small and local.

Nature Resilient. The fourth is a view of multistable states, some of which become irreversible traps, while others become natural alternating states that are experienced as part of the internal dynamics (Figure 1-1 D). Those dynamics result from cycles organized by fundamentally discontinuous events and nonlinear processes. There are periods of exponential change, periods of growing stasis and brittleness, periods of readjustment or collapse, and periods of reorganization for renewal. Instabilities organize the behaviors as much as stabilities do. That was the view of Schumpeter's (1950) economics, and it has more recently been the focus of fruitful scholarship in a wide range of fields—ecological, social, economic, and technical. These dynamics are the ones argued for ecosystems (Holling 1986). They have similarities in Harvey Brooks's view of technology (1986); recent views of the economics of innovation and competition (Arthur, Durlauf, and Lane, 1997); Mary Douglas's (1978) and Mike Thompson's (1983) view of cultures; Don Michael's view of human psychology (1984); and Barbara Tuchman's (1978) and William McNeill's (1979) view of history. It is a view of multiple stable states in ecosystems, economies, and societies and of policies and management approaches that are adaptive. But this view presumes a stationary stability landscape—stationary underlying forces that shape events. In this case, our cookie sheet has been molded and curved in three dimensions, but its basic contours are fixed over time (Figure 1-1 D). This "resilient worlder" view is also not wrong—just incomplete. There are, indeed, cycles of change that can move variables among stability domains, but those very movements contribute to the apparent fixed nature of the contours. Constrain those movements through policy actions, and the contours shift, as slow variables change. That can precipitate a more structural kind of surprise that is a con-

sequence of successful but myopic policy. Many of the examples of the pathology of resource management and regional development are just those kinds of structural surprises.

Nature Evolving. The emerging fifth view is evolutionary and adaptive. It has been given recent impetus by the paradoxes that have emerged in successfully applying the previous more limited views. Complex systems behavior, discontinuous change, chaos and order, self-organization, nonlinear system behavior, and adaptive evolving systems are all code words characterizing the more recent activities. They are leading to integrative studies that combine insights and people from developmental biology and genetics, evolutionary biology, physics, economics, ecology, and computer science. Profound innovations have been created and led by John Holland in his applications of genetic algorithms and development of complex adaptive system theory. His more recent work on a simple, highly visual model that illustrates the creation of complex structures by natural selection (Holland 1995) presents a way to explore the generation and selection of novelty in mathematical, economic, and social systems. In economics, some examples of early developments are in Anderson, Arrow, and Pines (1988). A nice review of later work is Sargent (1993), and a current collection of articles is presented in Arthur, Durlauf, and Lane (1997). Marco Janssen extends and applies those approaches to explore changing perspectives on future behavior in Chapter 9. It is a view of an actively shifting stability landscape with self-organization (the stability landscape affects behavior of the variables, and the variables, plus exogenous events, affect the stability landscape). Levin's recent book, *Fragile Dominion* (1999), gives an accessible and effective treatment of present adaptive, complex systems views for ecology.

Nature Evolving is a view of abrupt and transforming change. It is a view that exposes a need for understanding unpredictable dynamics in ecosystems and a corollary focus on institutional and political flexibility. We cannot, at this stage, invent a simple diagram to add this myth to those shown in Figure 1-1. In a sense, that is the purpose of the book—to develop a sufficiently deep understanding of Nature Evolving that its essential behavior and the relevant policies can be captured in a few paragraphs, a few simple models of real situations and a simple set of suggestive diagrams. Subsequent chapters provide the understanding to do just that using the theoretical framework of panarchy.

Many of the examples of successful resource exploitation followed by collapse are based on the above-mentioned myths of nature. The concepts of stability and resilience embedded in these caricatures can be given meaning in the metaphor of raft described in Box 1-2. These myths are useful underpinnings for understanding and action. Yet they reveal a paradox that goes back hundreds of years in thought. That is, if human exploitation leads to resource collapse, why haven't all ecological systems collapsed, and why are we humans still here? We discuss that paradox in the following section.